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SOME MOSAIC DISEASES OF PRUNUS SPECIES[1]

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IN THE ABSENCE of a visible fungus or bacterial pathogene, the diagnosis of a plant disease depends in a large measure upon the recognition of symptoms. This observation is particularly applicable in the study of diseases of deciduous fruit trees in California where there is found a relatively greater proportion of virus and nontransmissible diseases than is the case in more humid areas. It has seemed desirable, therefore, to assemble and to study, under comparable conditions, some of the prevalent virus diseases of deciduous fruit trees and to improve the criteria for distinguishing these from nontransmissible diseases such as exanthema and little-leaf, or rosette, the latter of which may cause symptoms on grape leaves strongly suggestive of a mosaic disease.

It is a rather remarkable fact that none of the several well-known virus diseases of stone fruits in eastern United States, namely, peach yellows, peach rosette, little peach, and phony peach, have been found in California. On the other hand, there are a considerable number of virus diseases of these plants in California, few or none of which seem to be established in the eastern states. Among the latter group, only cherry buckskin (*8*)[4] and peach mosaic (*3*, *6*) have been studied in any detail.

The earlier plan of this work, begun in 1932, involved the collection of those virus-type diseases that were found on deciduous fruit trees from which the more important were to be selected for further study. As the collections continued, however, and certain apparent interrelations between some of the diseases appeared, it became more and more

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[4] Italic numbers in parentheses refer to "Literature Cited" at the end of this paper.

difficult to single out one disease to the exclusion of others. As a consequence, collection and cross-inoculation with a number of these diseases have been continued to the present, and some of the seemingly minor diseases are set forth here as far as information is available, along with several which appear to be of considerable importance in the orchards of central California. This paper is limited to diseases of the mosaic type, using the term "mosaic" in a rather broad sense.

ALMOND MOSAIC DISEASES

Speckling and mottling of foliage of almond, *Prunus communis*, first called to notice by Gilbert L. Stout, is very prevalent in orchards of the

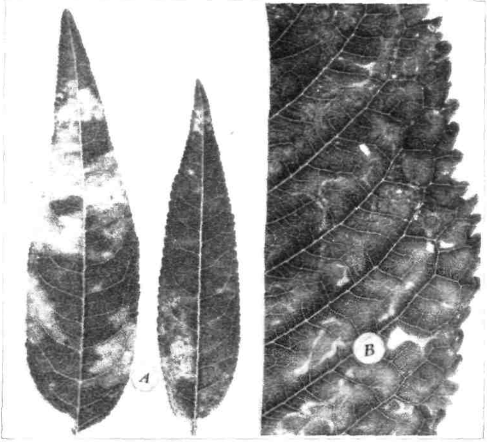

Fig. 1.—*A*, The calico disease of almond; *B*, part of a leaf from mazzard-cherry seedling inoculated with the almond-calico virus.

northern Sacramento Valley. It is not clear at present how many diseases are involved. While the symptoms on individual leaves are often conspicuous, the damage to the tree as a whole does not seem to be great (see also section on "Peach Mosaic Diseases").

A common symptom is a small, pale green to white, more or less star-shaped spot in the leaf blade. At other times large chlorotic blotches or

bands are seen, usually with little or no distortion. Material representing the latter symptoms, collected by Stout at Chico and designated by him as "calico" (fig. 1, *A*), was used to inoculate almond and peach. On small potted almond trees in the greenhouse, symptoms appeared as early as 4 months after inoculation, while on trees eight to ten years old symptoms were not seen on previously healthy branches until 19 months after inoculation.

On seedling peach trees inoculated with the affected almond material, a few leaves eventually developed large, pale-yellow blotches without pattern, the symptoms apparently becoming intensified as the leaf matured. These symptoms closely resembled some of those produced on peach out of doors by the cherry-mosaic-1 virus.

Inoculations with the above almond material to small sweet-cherry seedlings resulted in mild to striking symptoms within 7 weeks, varying considerably from plant to plant and in some leaves resembling symptoms which are found on cherry in the orchard (fig. 1, *B*).

APRICOT MOSAIC DISEASES

Mild but definite mosaic symptoms on apricot, *Prunus Armeniaca*, have been found on a few trees in each of three orchards in Solano and Yolo counties. Buds from one of these trees were used to transmit the disease (fig. 2) to seedling apricot trees. Trees budded in October exhibited symptoms near the points of inoculation the following May, but about 18 months were required for symptoms to appear in all parts of trees eight to ten years old. The symptoms in one such inoculated tree have been distinctly more severe than those seen in the original orchard trees. No certain symptoms have been seen thus far in seedling peach trees up to two and one-half years from the time of inoculation with this disease. In some inoculated apricot trees, but not all, a distinct shortening of nodes was visible the second or third year after inoculation. At present this disease is of interest chiefly because of the similarity of symptoms to those of a disease of peach and apricot treated later in this paper (p. 633).

CHERRY MOSAIC DISEASES

A considerable range of chlorotic symptoms has been seen on sweet cherry, *Prunus avium*. The infectious nature of some of these chloroses, however, is in considerable doubt. In fact, some of the common types of chlorosis which simulate virus symptoms, seem to be definitely not transmissible. Some of these have been grafted on apparently healthy sweet-cherry trees and the inoculated trees have remained symptomless for at

least two or three years, even the affected scions failing to retain the symptoms. Such a type shown in figure 3, *A* seems to be the result of unfavorable soil.

On the other hand, at least two types of mosaic of the sweet cherry are transmissible by grafting. One of these diseases, evidenced by chlorotic

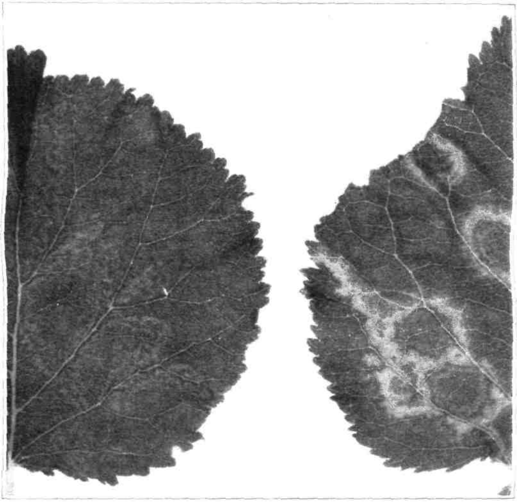

Fig. 2.—A mosaic of apricot.

blotches, lines, or rings (fig. 3, *B*), seems to be more apparent in the foliage of mazzard (*Prunus avium*) rootstocks than in the common top varieties of sweet cherries and altogether comparatively mild in effect upon the more common orchard varieties. Plants inoculated with this disease in October developed symptoms the following spring.

Symptoms somewhat similar to these were seen on a few trees of the varieties Windsor and Yellow Spanish in Wayne County, New York, in 1931. In a preliminary attempt to transmit the disease from Yellow Spanish to Black Tartarian in the greenhouse at Ithaca, New York, symptoms appeared the following spring but did not persist, and the

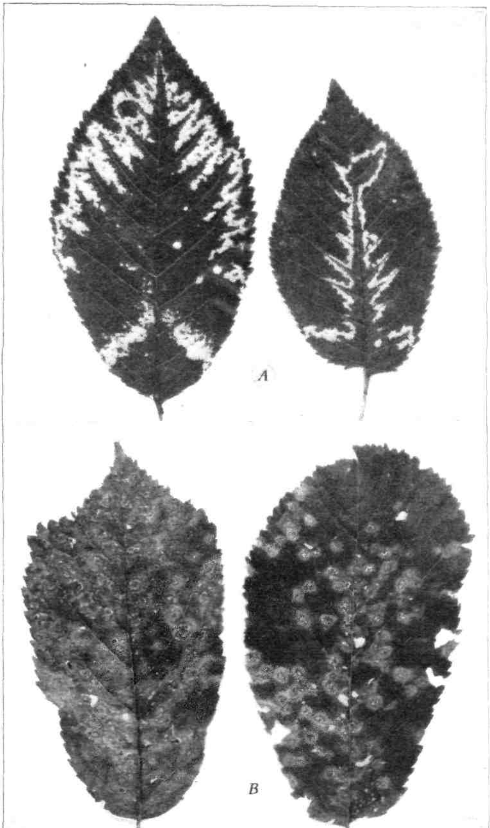

Fig. 3.—*A*, Noninfectious condition in sweet cherry apparently related to unfavorable soil; *B*, a mosaic of mazzard-cherry foliage.

results are considered inconclusive. C. E. F. Guterman very kindly noted the results of this experiment.

Another type of mosaic (fig. 4) is somewhat similar to "mottle leaf" reported from Oregon (*14*).[5] It is apparently distinct, however, from the disease treated under that name by E. L. Reeves in Washington

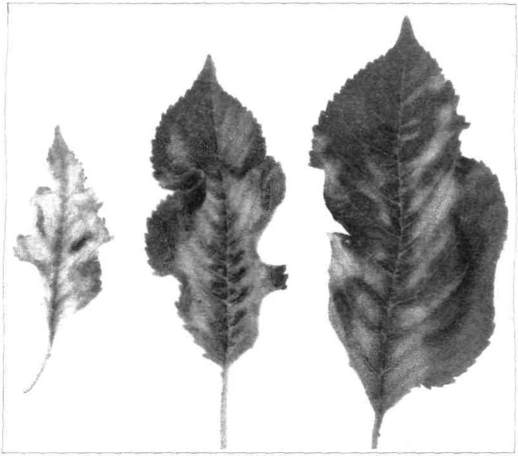

Fig. 4.—Early-season symptoms of cherry mosaic 1 on leaves of Napoleon variety; natural infection.

(*10*); Reeves has pointed out in one orchard in Napa County, California, the type of disease he has under study in Washington.

Since the name "mottle-leaf" has seemingly been applied to a disease distinct from that under consideration here, and since it is already in general use in this state to designate a nontransmissible disease of citrus, the disease treated in the following paragraphs will be designated "cherry mosaic 1." This disease has been seen on Black Tartarian, Chapman, Napoleon (Royal Ann), and Republican (Black Republican), and

[5] H. R. McLarty, in a paper entitled "Cherry Mottle Leaf," presented before the Northwest Association of Horticulturists, Entomologists, and Plant Pathologists at Kelowna, B. C., July 17–19, 1935, expressed the opinion that the disease studied by him in British Columbia was the same as that described by Zeller in Oregon (*14*). In this paper McLarty presented evidence of the infectious nature of the disease.

a variety known locally as "Long Stem Bing," and has been observed in Butte, Napa, Riverside, Solano, Sonoma, and Sutter counties. The variety Napoleon seems to be somewhat more susceptible than the others mentioned (as was the case in Oregon).

The early-season symptoms of cherry mosaic 1 are small to large chlorotic blotches in the blade of the young leaf followed by distortion as the green portions of the leaf continue to expand (fig. 4). The chlorotic areas of such leaves often drop out, and many of the leaves fall by midsummer. In the latter part of the season a milder mottling of leaves with little or no distortion is often seen on affected trees. Rather consistently associated with this disease in late stages is the appearance of compact tufts of small and sometimes distorted leaves from latent buds on large branches of older trees. In advanced stages of the disease, the fruit is scant and in some varieties tends to be somewhat misshapen.

Potted trees of the Napoleon variety and seedlings inoculated by affected scions or buds in May and June developed symptoms early the following spring. Observations thus far, however, indicate that in general the spread of this disease is rather slow in orchards. For example, in one orchard of Black Tartarian and Napoleon, 5 of 85 trees were noted as affected in June, 1935, and only 6 of the 85 trees were unmistakably affected in May, 1938. An apparent exception to this general impression was encountered in one orchard of 80 acres of Republican and Napoleon where the grower had seen only 5 or 6 affected trees in the entire orchard during the five years preceding 1937. In a portion of this orchard, 5 of 100 trees examined in May, 1928 (mostly Napoleon) were affected and 8 others appeared to be so.

Potted peach trees inoculated by inarching or budding with affected cherry material have shown a considerable range of symptoms, but mild for the most part. These symptoms include in some cases distinct chlorotic blotches in the expanding leaf resembling the symptoms on young cherry leaves. On other plants mild to rather strong chlorosis is produced, typically without any definite pattern, and with little or no distortion. Preliminary tests indicate that cherry mosaic 1 is transmissible by inarching to almond and *Prunus Mahaleb*, producing rather mild symptoms on these plants.

A disease of sour cherry, *Prunus Cerasus*, which causes a mottling of the leaves, is common both in New York orchards and in the comparatively few trees that have been examined in California. These trees are of interest here chiefly for the reason that they are sometimes used as stocks for sweet cherry.

The symptoms of the disease of the sour cherry in the two states are

sufficiently similar to suggest that the cause is, in some cases, the same. Usually the affected leaf develops pale-green to yellow blotches with some distortion. Occasionally definite chlorotic bands and rings appear. A symptom which seems to be a part of the same complex in both states consists in small rings clearly apparent by reflected light but invisible or nearly so by transmitted light and without appreciable chlorosis.

Sweet-cherry scions and buds grafted on affected sour-cherry trees (morello type) in California have not shown any symptoms clearly related to the sour-cherry disease. Peach trees inoculated with this disease both at Ithaca, New York, and at Berkeley, California, developed mild mottling of leaves, and at Berkeley, strong vein swelling when the plants were kept in the greenhouse.

Another disease occasionally seen in leaves of mahaleb rootstocks, on some of which sweet cherries are growing, produces symptoms usually consisting in rather broad chlorotic bands. This type of mosaic was readily transmitted by grafting to healthy mahaleb trees, the symptoms appearing within 4½ months after inoculation. However, no specific effect of such diseased stocks is apparent on the sweet-cherry trees grown on them for several years.

PLUM AND PRUNE MOSAIC DISEASES

At least two types of mosaic on the Japanese plum, *Prunus salicina*, and two on prune, or European plum, *P. domestica*, have been under observation.

One of the mosaics on the Japanese plum has thus far been recognized only in a single planting of the variety Santa Rosa (*Prunus salicina*) in Vacaville, Solano County. Symptoms are mild, consisting in pale-green blotches, lines, and rings in the leaf blade (fig. 5, *C*). There is no evidence as yet, after five years from the first observation, that this disease is causing appreciable reduction in vigor of the trees. The disease is transmitted by buds to peach seedlings in which the symptoms in the greenhouse consist in mild mottling without any very definite pattern. This disease will be referred to later (p. 642) as the "Vacaville plum mosaic." It is similar to a mosaic of plum, transmissible to peach, which has been reported from Kentucky (*13*).

A second disease or group of similar diseases has been found on the Santa Rosa plum, and more recently on other varieties, in Eldorado, Mendocino, Placer, Santa Cruz, Solano, and Yolo counties. The typical symptoms on the Santa Rosa are rather small, completely chlorotic spots more numerous toward the distal end of the leaf blade (fig. 5, *A*). The Duarte variety in one orchard and an unnamed variety in another dis-

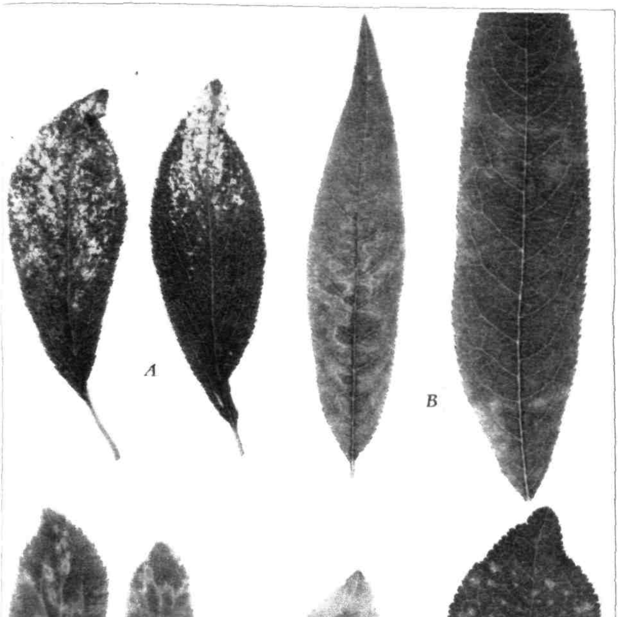

Fig. 5.—*A*, A mosaic on Santa Rosa variety of Japanese plum, natural infection at Aptos; *B*, Standard-prune-mosaic symptoms on seedling peach leaves; *C*, Vacaville plum mosaic on Santa Rosa variety; *D*, mosaic of Standard prune, natural infection at Live Oak.

played symptoms resembling those on Santa Rosa while the myrobalan (*Prunus cerasifera*) shoots from the rootstocks of affected trees in these orchards bore strong lines, bands, and vein clearing. The varieties Inca, Kelsey, and Sharpe's Pearl were also seen with symptoms similar to those of Santa Rosa, while the Del Norte in one orchard exhibited vein clearing only.

The latter disease of the Santa Rosa plum was transmitted by grafts to healthy Santa Rosa trees, and the myrobalan from one of the orchards mentioned was used successfully in transmitting the disease to healthy myrobalan plants.

Observations thus far indicate that this disease impairs the vigor of the trees appreciably but probably not greatly, at least in any short period of years.

A mosaic of Standard prune was noticed by C. E. Scott and H. H. Thornberry in October, 1935, in an orchard at Live Oak, California. Not less than 80 or 90 per cent of the trees in this orchard are affected, and there seems to be a slow but eventually considerable decline in vigor of affected trees. A small lot of trees of this variety purchased from a local nursery in 1937 all appeared to be affected by the same disease.

Typical symptoms on the prune are few to many small chlorotic spots, often more numerous in an area toward the tip of the leaf and coalescing to cause distortion and dropping out of parts of the leaf blade. (fig. 5, *D*). Unlike most of the diseases under consideration in this paper, this disease is more apparent in midseason than in early spring or in the greenhouse than out of doors, which indicates that a relatively high temperature is favorable for its development.

The prune orchard at Live Oak is interplanted with J. H. Hale peach trees, and the prune trees are growing on peach roots. No symptoms have been seen on the J. H. Hale trees that seem to be clearly related to the prune disease, but shoots from the peach rootstocks of the prune trees occasionally exhibit a rather mild mottling of the leaves. Also when peach seedlings were inarched in the greenhouse with affected Standard prune in June, 1936, the peach leaves developed a swelling of the veins by November of that year, and the following spring, a mottling varying from mild and rather indefinite to very striking lines and rings (fig. 5, *B*).

A disease of Sugar prune, noticed by W. D. Butler and M. R. Harris in an orchard near Napa, California, is similar to that on Standard prunes in appearance, with the difference that the basal part of the leaf is more often affected, and there is more tendency for the affected tissues to drop out. When healthy Sugar prune was inoculated in the green-

house by inarching with affected Standard prune (from Live Oak), only doubtful symptoms were seen on the Sugar prune the following year. On orchard trees of Sugar prune inoculated with affected buds of the same variety in July, 1936, symptoms were seen in August, 1938, only on shoots which grew from the affected buds. Likewise, inoculations of Agen (French) prune, President plum, peach seedlings, and *Prunus subcordata* have failed thus far to produce symptoms except that the peach leaves exhibited a marked vein swelling the year after inoculation.

The diseases of Standard and Sugar prunes are distinct in appearance from the virus disease of Italian Prune (Fellenberg) found in western New York (*11*).

PEACH MOSAIC DISEASES

Mosaic diseases of the peach, *Prunus Persica*, are of particular interest at this time because of the destructive disease (*1*, *6*) found in several southwestern states, including southern California, and designated heretofore merely as "peach mosaic." This disease will be referred to when necessary in the present paper as the "Texas peach mosaic," since it was first found in that state. A distinct disease designated as "asteroid spot" has also been found on peaches in southern California (*4*).

In addition to the several mosaic diseases already described in this paper which may be transmitted by inoculation to the peach, at least[6] one distinct mosaic-type disease has been found occurring naturally on peaches in central California. This disease is of especial interest in several ways and is discussed in some detail. It is known at present in only two orchards in the vicinity of Winters, California, and will be referred to as the "Winters peach mosaic."

INVESTIGATIONS OF WINTERS PEACH MOSAIC

Symptoms.—The most conspicuous symptoms of Winters peach mosaic are in the leaves and leaf buds and these are most readily seen at the beginning of the growing season. Pale-green to pale-yellow, oblong, feather-edged blotches appear along the midvein or larger lateral veins before the leaves are fully expanded, which result in distortion of the lamina and often dropping out of the chlorotic parts (fig. 6, *A*). Later in the season some leaves are seen with milder symptoms of the sort shown in figure 6, *B*, and rarely, a leaf is seen with definite chlorotic lines and rings.

[6] Mild mosaic mottling on a flowering-peach variety at Santa Clara and another near Fairfield on a fruiting variety (first noticed by L. C. Cochran) have not been studied in any detail.

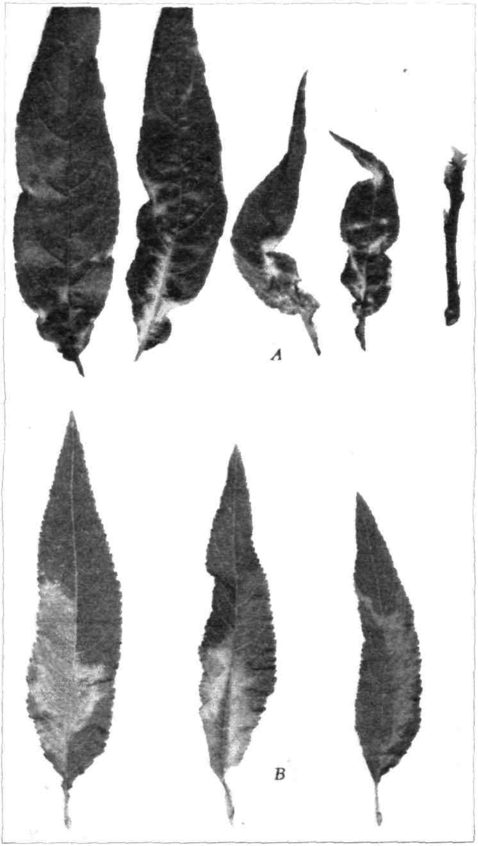

Fig. 6.—Winters peach mosaic: *A*, foliage symptoms and arrested buds of seedling peach; *B*, foliage symptoms on leaves of Elberta peach in the field in August.

On severely affected branches, the leaf buds often push out pale leaf tips for a few millimeters and then remain practically unchanged for a period of several weeks (fig. 6, *A*). Eventually these branches die back or a few buds produce compact clusters of small narrow leaves, often somewhat curved laterally, and usually with no conspicuous mottling. A considerable number of affected peach trees of both Elberta and Muir have died in the two orchards under consideration, but there is some evidence that unfavorable soil conditions have contributed to this loss.

When potted peach trees are inoculated in the greenhouse, most of the early-season symptoms found in the orchard are observable. The symptoms on these small trees, mostly seedlings, are on the whole more severe than those in the orchard and seem to be more severe at the onset of disease than later, on smaller trees than on larger trees, and when a scion is used as inoculum than when a bud is used. When a potted tree is cut back to within a few inches of the soil level and inoculated by grafting with a diseased scion, the tree seldom makes appreciable growth afterward, usually dying within a few weeks or months. When trees in the greenhouse are inoculated by budding after considerable foliage has developed, the youngest leaves at the time symptoms appear resemble those in the orchard in early spring; leaves somewhat older develop similar but small chlorotic areas; still older leaves develop numerous minute chlorotic spots in the leaf blade without distortion; while the oldest leaves exhibit no symptoms.

No symptoms in the flowers have been noted. Only a few flowers of affected peaches, other than Elberta and Muir, have been seen.

Fruit development varies from a fair crop to a few or none on affected branches or trees, more or less in proportion to the stage of development of the disease. Many Elberta fruits on affected trees in 1937 grew for a time, but remained slender and finally withered and dropped. This may have been due to a combination of low vigor and poor pollination. Fruits on affected Muir peach trees sometimes develop appreciable irregularities in shape (fig. 7) but not so pronounced as in the case of the Texas peach mosaic (*6*) in some varieties.

Experiments with Winters peach mosaic on other *Prunus* species have been made. On apricot, affected leaves in the orchards and in the greenhouse usually develop rather large chlorotic areas more nearly circular than on peach and rather frequently exhibit clearly defined chlorotic lines and rings (fig. 8, *A*). The affected areas often drop out but may persist for several months. There is some tendency also in the apricot for the buds to be arrested in early stages. On the whole, the Winters peach mosaic is distinctly milder on apricot than on peach.

No flower or fruit symptoms have been recognized on apricots.

The Winters peach mosaic on apricot is distinguishable from the disease mentioned earlier in this paper (p. 625) by greater severity of symptoms and by the failure of the latter to affect peach.

Only a few almond trees that appear to be affected by Winters peach mosaic have been found in orchards, and the identity of the disease on

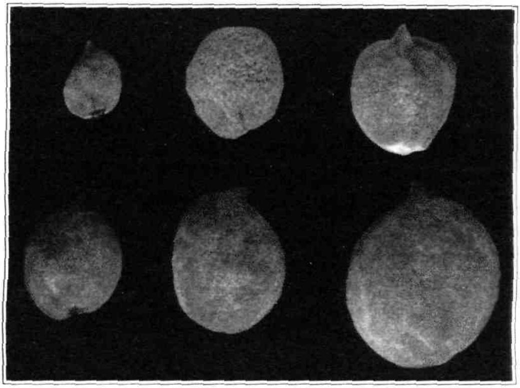

Fig. 7.—Dwarfing and malformation of Muir peach fruits from trees naturally infected by Winters peach mosaic.

these is in some doubt. In these cases, part of the leaf blade or all of it is strikingly chlorotic in early spring (fig. 8, *B*), and later, compact tufts of leaves appear somewhat similar to those sometimes seen on peach, but larger.

The fruits of these trees are irregular in shape, but somewhat similar fruits are rather common in central California on trees not always displaying any other symptoms.

Symptoms on Texas and seedling almond trees inoculated in the greenhouse with the Winters-peach-mosaic virus from peach or apricot vary from mild to severe, consisting in chlorotic spots on young leaves and tufting of older leaves which are often undulant and laterally curved as on some of the trees in the orchard. There is a tendency here also for arresting of the buds (fig. 9), which may die afterward or develop slowly into distinct rosettes.

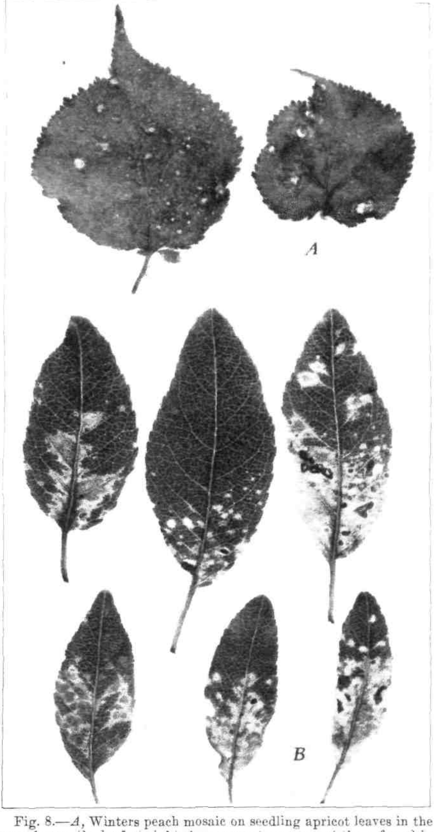

Fig. 8.—*A*, Winters peach mosaic on seedling apricot leaves in the greenhouse, the leaf at right shows symptoms nearest those found in the orchard. *B*, A mosaic on Texas variety of almond, natural infection, early-season symptoms.

Fig. 9.—Winters peach mosaic on almond seedlings produced by inoculation in greenhouse. The larger plant was inoculated at the point indicated by the arrow on June 15, 1937, and photographed on February 23, 1938. Only the buds beyond the point of inoculation show symptoms. The plant at left is affected throughout and is in a more advanced stage of growth.

Symptoms of the Winters peach mosaic on plants other than peach, almond, and apricot have been seen only on plants inoculated and kept in the greenhouse. Some will be mentioned in the following sections.

Sap and Temporary Inarching Inoculations with Peaches.—A number of experiments were made in which affected peach leaves were ground

in a mortar in water alone or in water plus various materials, such as agar, gelatin, gum acacia, and the natural gums of several stone fruits. The sap was then rubbed on young peach leaves using carborundum (*9*) as an abrasive. The results to date, involving 61 trees, have been uniformly negative.

In a single experiment 5 healthy peach seedlings were inarched on diseased plants and bound with rubber budding tape in the same way that other inoculations were made except that no wax was used. The inoculated plants were detached after 79 hours, and the wounds were covered with a proprietary grafting tape. At the end of 12 weeks no infection was apparent on these plants. For a peach mosaic from Colorado, Kunkel (*7*) has recently shown that infected buds must be left in inoculated plants for a minimum of 2 days in order to produce infection.

Grafting Inoculations with Peaches.—The Winters peach mosaic was transmitted readily from peach to peach in the greenhouse by buds, scions, or inarches, not often failing even when the inoculum did not survive, as was frequently the case with diseased buds. The minimum incubation period observed was slightly less than 4 weeks.

Grafting Inoculations with Related Species.—Although it does not necessarily follow that a susceptible plant will become inoculated under natural conditions, for several reasons it is desirable to know, as far as possible, the range of susceptible plants, particularly for a disease likely to be dealt with by eradication. Accordingly, inoculations on a small scale were made on a considerable number of species more or less related to peach. In distantly related plants, and in most of the others, inarching was used as the method of grafting. With this method, graft unions can be obtained which would not be possible with buds and scions. Presumably also this method exposes the test plant to a greater mass of inoculum. It is not possible in all cases, however, to determine whether a union has been made even when both plants produce abundant callus. Neither has an actual growth union been shown beyond question to be essential for the transmission of this disease. At any rate, negative results are held as doubtful unless a definite union was established.

Infection with Winters peach mosaic was obtained with about equal facility from peach to apricot and apricot to peach as from peach to peach. Infections have been obtained from both peach and apricot to almond but with more difficulty. Symptoms in the almond were slow in developing, in some cases severe (fig. 9), but frequently mild in the end; a few failed to develop any marked symptoms even after the virus had been recovered from them by inoculation to peach or other plant.

Symptoms sometimes appear above and below the point of inoculation

at about the same time, but more often they appear first above. In several almonds inoculated with Winters-peach-mosaic virus early in 1937, strong symptoms appeared in the spring of 1938 in all leaves distal to the point of inoculation but not elsewhere on the plants during 1938 (fig. 9). However, the virus was demonstrated in 7 of 10 scions taken from seemingly healthy parts of such plants on July 11, 1938.

Although several almond trees, and one in particular, have been seen in the orchard which seemed to be affected by the same disease, several attempts to produce the typical disease in peach or apricot by inoculation from such almonds have yielded inconclusive results. When scions from the most severely affected almond tree found in the orchard (fig. 8, *B*) were grafted on peach or almond in the greenhouse in March, 1937, a few leaves on the stocks of both peach and almond bore symptoms a few weeks later which resembled those of the typical disease, but the symptoms did not persist, and some of these plants appeared to be healthy as late as July, 1938.

Inoculation of plants of the desert peach, *Prunus Andersonii*, growing on their own roots has thus far failed to produce symptoms even when they made good graft unions and were left exposed to the inoculum for several months. But 2 of several scions taken from that part of an inoculated plant distal to the point of inoculation and grafted on healthy peach seedlings in 1937 developed very pronounced symptoms in the spring of 1938 (fig. 10) consisting in compact tufts of small leaves and suppression of shoot growth.

Of 7 cherry trees (*Prunus avium*) inoculated in March and June, 1937, one began to develop dwarfed and distorted leaves 2 months after inoculation and in the spring of 1938 was severely affected with mostly small pale leaves slow in appearing and with no shoot growth. The virus was recovered from this plant by inoculation to peach. Doubtful symptoms were seen on 2 of the other cherry trees, but attempts to recover the virus from them have not thus far been successful.

Small-scale attempts to infect *Prunus cerasifera* (myrobalan), *P. domestica* (Sugar prune and Tragedy plum), *P. ilicifolia*, and *P. lusitanica* seem to have failed as have attempts to recover the virus from myrobalan and Sugar prune.

Prunus Mume was infected by inoculation from apricot with symptoms resembling those of the apricot.

Inoculation of cultivated strawberry and red raspberry failed to produce symptoms. No attempt was made to recover the virus.

The single-flowered type of *Kerria japonica* inoculated in 1937 developed a rather indefinite mottling of the foliage in 1938 hardly suffi-

cient to remove the plant from the symptomless-carrier class, but the virus was recovered readily from this plant by inoculation to peach seedlings.

This virus was transmitted with some difficulty to Gloire des Rosomanes (Ragged Robin) rose (2 of 6 inoculated plants) but with very

Fig. 10.—At left, Winters peach mosaic on desert peach, *Prunus Andersonii*, grafted on peach seedling root. At right, the *P. Andersonii* plant from which the affected scion at left was taken has no symptoms.

pronounced symptoms on those plants that became infected. A characteristic noted on plants of other species affected by this disease but more conspicuous on the rose, is the tendency for extremely chlorotic areas to develop considerable green pigment with advancing age of the leaf. Some details of symptoms are treated in the accompanying paper on mosaic diseases of the rose (*12*).

Attempts to Induce Immunity.—When it became apparent that the desert peach, *Prunus Andersonii*, did not develop symptoms within several months after inoculation with Winters-peach-mosaic virus, and that the virus did not seem to pass readily through this plant, shoots of affected cultivated peach trees were inarched in 1937 on plants of *P. Andersonii* and later detached so that they were entirely supported by

the latter. Six such combinations survived the following winter of 1937–38. The peach scions in 3 of these cases died the following spring without producing new leaves. Two others exhibited symptoms, at least one of them as severe as with peach on peach root. A single scion remained healthy throughout 1938 but possibly for the reason that it had not yet been invaded by the virus at the time it was detached from the parent plant. None of the *P. Andersonii* plants in this group, however, bore symptoms up to December, 1938, nor have any others of this species while growing on their own roots, although infection has been obtained in *P. Andersonii* growing on peach roots. This may or may not be comparable to the interesting case of apparent recovery of diseased scions when grown on resistant or immune stocks which has been reported for the bunch disease of pecan (*5*).

As a result of cross-infection experiments and the types of symptoms displayed, the following diseases were selected to use in attempts to immunize peach seedlings against the Winters peach mosaic: almond calico, cherry mosaic 1, Vacaville plum mosaic, and the Standard prune mosaic. Twelve, 14, 10, and 10 seedling peach trees, respectively, were inoculated with these diseases by scions or by inarching in October, 1937, and after overwintering were inoculated by buds carrying the Winters-peach-mosaic virus inserted near the ground line in March, 1938. While this experiment is not entirely concluded at the time of writing, 6, 6, 7, and 5 plants, respectively, in the 4 groups have developed symptoms of the Winters peach mosaic, and no clear reduction in severity has been noted.

DISCUSSION

A determination of the severity of the mosaic diseases discussed in this paper will involve not only the inoculation of varieties and species related to those in which the diseases occur naturally but also the growing of affected trees under orchard conditions known to be relatively favorable for the growth of the particular trees under consideration. In many cases, moreover, the trees must be kept under observation for several years, for a slow decline may easily pass unnoticed but eventually cause more loss than a disease which kills the trees in a single season.

The relation of these diseases to each other and to those in other states and countries is in some cases uncertain. The confused state of the knowledge of such diseases is illustrated by recent papers from central Europe (*2*). A final determination of the relation between similar diseases in different localities would often require the comparison of infected plants side by side grown under the same conditions. This is not feasible with anything short of equipment for complete isolation.

Symptoms on the several species and the results of cross-inoculations indicate that almond calico, cherry mosaic 1, and the Winters peach mosaic may be related, but certain of the symptoms and the results of an immunization experiment seem to show that they are not identical.

The control of these diseases in established orchards whenever deemed necessary will no doubt consist chiefly in the eradication of affected trees, as is the case with other virus diseases of fruit trees. In a few instances, however, there is evidence that spread of the diseases in the orchard may be less important than that in the nursery. At any rate, a complete control program must inevitably involve the use of scion wood from trees which are carefully examined at several seasons of the year for symptoms of virus diseases.

SUMMARY

One disease or more of the mosaic type have been found in central California affecting each of the following species of *Prunus: P. Armeniaca, P. avium, P. cerasifera, P. Cerasus, P. communis, P. domestica, P. Mahaleb, P. Persica, P. salicina.* These vary in effect upon the known suscepts from mild to severe. Symptoms are described and illustrated.

A mosaic of *Prunus avium*, designated as "cherry mosaic 1," is rather widely distributed in the state and is transmissible to *P. Persica* and apparently to other species.

Almond calico is transmissible to *Prunus avium* and *P. Persica* with rather strong symptoms on cherry.

At least two mosaic diseases were found in Japanese plum, *Prunus salicina*. One of these, the Vacaville plum mosaic, on the Santa Rosa variety was transmitted to peach seedlings.

Mosaic diseases of Standard and Sugar prune (*Prunus domestica*) are similar in certain symptoms but the evidence to date indicates that they are not identical. The disease of Standard prune was transmitted to peach.

A mosaic of *Prunus Persica,* known thus far only in one locality at Winters, is designated "Winters peach mosaic." It is in many respects similar to the mosaic of peaches in Texas, southern California, and elsewhere. This disease occurs naturally on peach, apricot, and probably on almond. It has been transmitted by grafting to *Prunus Andersonii, P. Armeniaca, P. avium, P. communis, P. Mume, Kerria japonica,* and *Rosa* sp. (Ragged Robin).

An attempt to immunize peach seedling trees against the Winters peach mosaic by the use of several milder mosaic viruses was not successful.

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MOSAIC DISEASES OF THE ROSE IN CALIFORNIA

H. EARL THOMAS AND L. M. MASSEY

MOSAIC DISEASES OF THE ROSE IN CALIFORNIA[1]

H. EARL THOMAS[2] AND L. M. MASSEY[3]

ABOUT A QUARTER of a century before virus diseases as such began to be recognized, evidence of graft transmission of a chlorosis of the rose was recorded in France (*12*).[4] However, mosaic as a disease of importance in rose culture did not attract attention until about 1928 (*14*). Mosaic then for several years excited an unusual amount of comment and controversy (*7, 8, 18*) which has been only partially justified by more extensive observations and experiments (*7, 13, 17*). It is now apparent, at any rate, that the rose may be affected by virus diseases of some importance and may serve as a potential source of virus for other plants (*10*).

The material presented in this paper relates to the mosaic type of disease only. The necrotic diseases reported from the eastern United States (*2*) and abroad (*4, 5*) have not been found in California.

SYMPTOMS

As early as 1933, evidence began to appear in this work indicating that not one mosaic disease occurs among the cultivated roses but several. Since some of these were not recognized as distinct until recently, it will not be possible to treat them separately throughout this paper. For convenience these will be designated as "rose mosaic 1," "rose mosaic 2," and "rose mosaic 3," and the corresponding viruses distinguished by their respective numbers.

In roses grown out of doors, lime-induced chlorosis without malformation is rather common, notably in the Santa Clara Valley. In such cases the leaf blade becomes uniformly yellow rather than mottled. This may obscure or inhibit development of symptoms of the mosaic diseases and may in some cases be confused with them. Diagnosis in the field is also complicated very frequently by insect injury (*7*), particularly that produced by leafhoppers.

Types of variegation are encountered occasionally, which appear to be entirely genetic in origin. Scions of one such rose (fig. 3, *A*) were grafted on *Rosa odorata* and kept under observation for several years.

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[4] Italic numbers in parentheses refer to "Literature Cited" at the end of this paper.

No evidence of transmission to the stock nor of change in symptoms toward those of the infectious mosaics was ever noted.

Rose Mosaic 1.—This disease on such cultivated varieties as Hollywood, Pilgrim, and Premier Supreme (fig. 1) produces small chlorotic spots somewhat angular or fringed in appearance due to the clearing of small veins and veinlets adjacent to the spot proper. The chlorotic areas

Fig. 1.—Rose mosaic 1 in leaves of the Hollywood variety.

are more numerous at or near the midvein and often appear in greater numbers near the base of the leaflet. The leaf blade around the spot is often more or less distorted. Occasionally pale bands or lines appear on leaves of affected plants, more often out of doors, but it is not known whether these are symptoms of mosaic 1. There may be no reduction in vigor or the plant may be slightly to severely dwarfed, according to the variety and, no doubt to some extent, to the growing conditions. On the four common stocks *Rosa chinensis* var. *Manetti*, *R. multiflora*, *R. odorata*, and Gloire des Rosomanes (better known in California as "Ragged Robin," which term will be used hereafter in this paper), the symptoms

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are mild, seldom exceeding in severity the small chlorotic flecks shown in figure 2. Blossoms of the top varieties may be normal or nearly so in appearance or severely dwarfed and pale in color. Usually a part of the

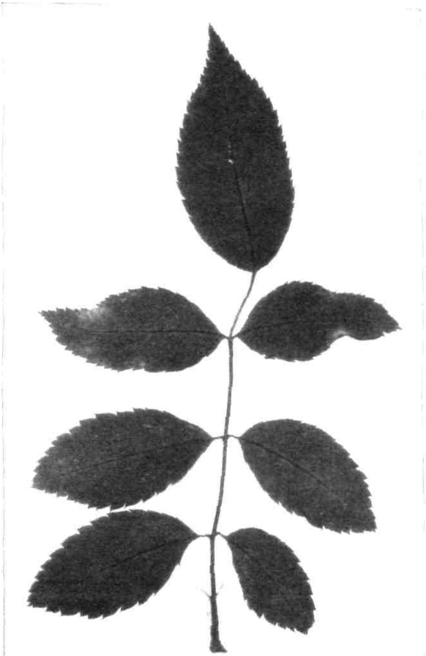

Fig. 2.—Rose mosaic 1 in *Rosa multiflora*. Only a few small chlorotic spots are present.

corolla is attenuated, leaving the flower unsymmetrical and of little commercial value. Rose mosaic 1 seems to be the principal mosaic disease of roses grown under glass, whereas mosaics 2 and 3 are more fre-

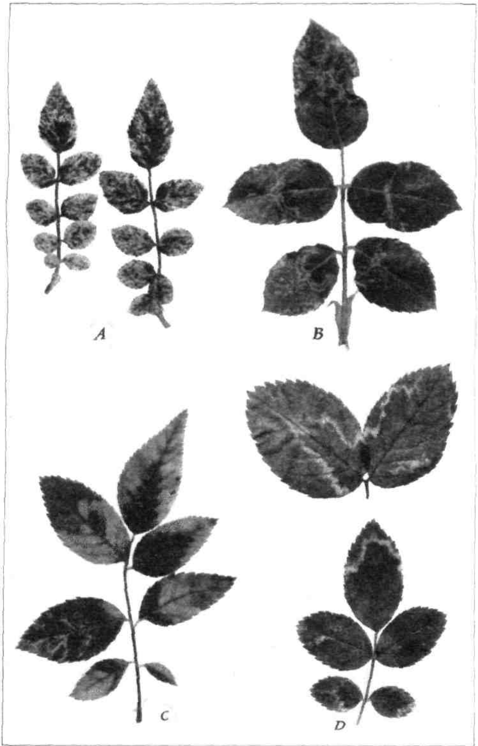

Fig. 3.—*A*, Two small rose leaves representing a noninfectious variegation; *B*, rose mosaic 2 in Belle of Portugal; *C*, rose mosaic 2 in *Rosa odorata; D*, rose mosaic 3 on *R. chinensis* var. *Manetti*. Note the oak-leaf pattern on leaves in *B* and *D*.

quently noticed in plants grown in parks and gardens. Mosaic 1 has been seen in gardens and nurseries, however, and may be more generally prevalent out of doors than is indicated by the observations to date. Only a very detailed survey early in the season could determine this point with certainty.

Rose Mosaic 2.—The disease designated as "rose mosaic 2" was first observed in the variety Cecile Brunner in a city park at San Jose. Although somewhat variable in symptom expression even on the same plant, it is typically characterized in such varieties as Belle of Portugal, Cecile Brunner, Hollywood, and Independence Day by chlorotic lines, bands, and broad blotches in the leaf blade with or without distortion (figs. 3, *B*, *C*, and 5, *A*). The symptoms, on the whole, are distinctly more conspicuous than those of mosaic 1 on both top varieties and stocks. In some cases the disease seems to dwarf the plants somewhat; in others little or no dwarfing is apparent. No specific symptoms of blossoms have been noted for this disease.

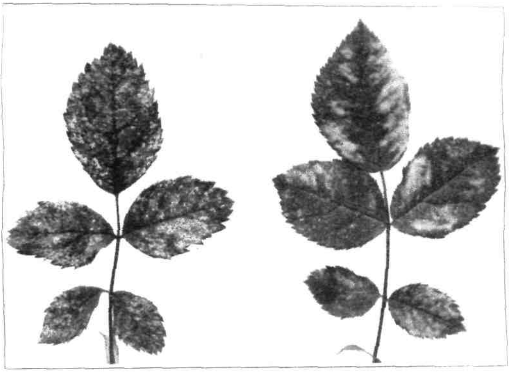

Fig. 4.—Rose mosaic 3 in Ragged Robin.

Rose Mosaic 3.—Specimens of diseased plants designated as "rose mosaic 3" were obtained in the variety Souvenir de Claudius Pernet from a garden in Sacramento through the courtesy of D. G. Milbrath. Mosaic 3 produces symptoms on the four common stocks which are similar to those of mosaic 2 but on the whole are more severe, in some cases

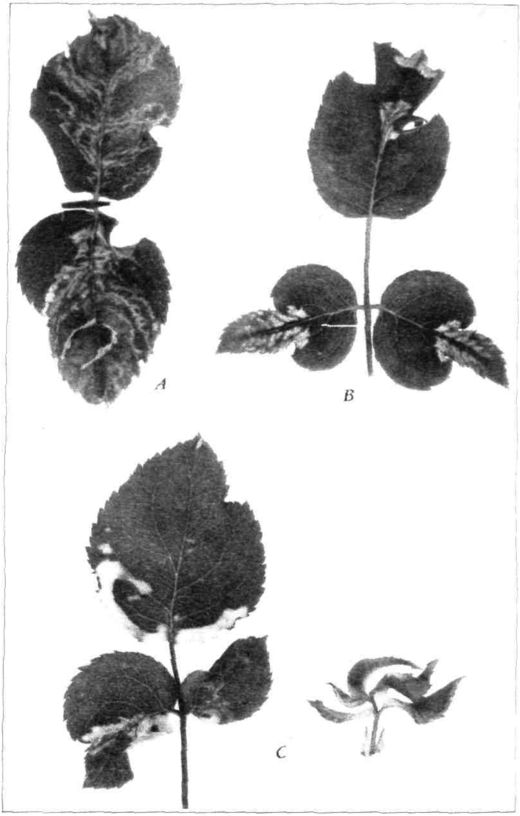

Fig. 5.—*A*, Rose mosaic 2 in Hollywood variety (pair of leaflets); *B*, apple mosaic in same variety; *C*, rose mosaic 3 in same variety, showing mottling and severe distortion.

causing distinct dwarfing. There is also more tendency toward broad chlorotic blotches in the leaf blade and few lines and rings (figs. 3, *D*, 4, and 5, *C*). Occasionally a conspicuous oak-leaf pattern (fig. 3, *D*) is produced, and not infrequently part or all of a leaf may exhibit a pronounced clearing of the veins while other leaves on the same plant bear the more common symptoms.

Other Mosaic Diseases Transmissible to Roses.—In addition to the three rose mosaics described above, the common apple mosaic is transmissible to rose (*10*) producing symptoms on Belle of Portugal similar to those of mosaic 2 but with the tendency, much more pronounced in Hollywood and Independence Day, toward marked constriction and chlorosis in a fairly definite broad band across and near the middle of the leaflet blade (fig. 5, *B*). Flowers of the Hollywood variety affected by the apple mosaic are reduced in size, and the color is lighter than normal.

Also may be mentioned here the symptoms on the rose of a peach mosaic collected at Winters, California. This mosaic is similar to but distinct from the mosaic of peach reported from Texas, Southern California, and elsewhere (*11*). The Winters peach mosaic inoculated to rose by inarching has produced marked chlorosis in leaves of Ragged Robin, sometimes rather general (fig. 6, *A*), but often limited to shorter or longer cleared areas along the larger veins. On *Rosa odorata* a few pale-green lines and rings were produced a few weeks after inoculation but these faded and did not reappear on new leaves up to more than a year from the time of inoculation. Symptoms of this disease on the Hollywood variety are similar to those on Ragged Robin, but less severe.

Several cases have come to notice which suggest the presence of still other diseases, but the relation of these to the diseases designated above has not been sufficiently tested to permit any conclusions. Among these is a specimen of Independence Day growing in a garden in Oakland, with vein clearing as the only symptom. This was grafted on *Rosa chinensis* var. *Manetti* and kept at Berkeley for more than a year alternately in the greenhouse and out of doors but remained free, or virtually so, of any other symptom and produced no symptoms on the *R. chinensis* var. *Manetti* stock.

PLANTS AFFECTED

The symptoms of rose mosaic 1 have been seen by us or illustrated by earlier workers (*7, 16*) on the following rose varieties: American Beauty, Angele Pernet, Autumn, Better Times, Briarcliff, Feu Joseph Looymans, Gruss an Coburg, Hollywood, Hortulanus Budde, Madame Butterfly, Matchless, Mrs. F. R. Pierson, Pilgrim, Premier, Premier Supreme, Radiance, Rapture, Red Radiance, Rose Hill, Southport, and

Ulrich Brunner. The symptoms on Ulrich Brunner were seen out of doors and consisted of numerous small chlorotic spots with little tendency to be aggregated near the midvein or to produce distortion of the leaflet. These symptoms persisted on this variety in the greenhouse, but when such material was used to inoculate Hollywood, the latter developed symptoms which seemed typical of mosaic 1. A considerable number of other varieties have been listed by earlier workers as subject to rose mosaic and some of them are no doubt affected by the disease here delimited as rose mosaic 1.

No attempt is made at present to classify the above varieties or those to follow according to the severity of the disease. It is apparent, however (*17*), that differences in susceptibility do exist among varieties. For example, the variety Mrs. Charles E. Russell was inoculated with each of the viruses 1, 2, and 3. Only mild symptoms, at most, were produced by any one of these. Mosaic 1 in Independence Day produced no symptoms at all, although the virus was shown to be present.

Among the stocks, Ragged Robin seems to be more affected than *Rosa chinensis* var. *Manetti*, with *R. Multiflora* and *R. odorata* intermediate between them.

Potted plants of the native species *Rosa californica*, *R. gymnocarpa* and *R. nutkana* were inoculated in the greenhouse by inarching on affected plants of cultivated varieties. No symptoms have been seen on the inoculated plants up to 12 months from the time of inoculation. Attempts to recover the virus from these have not been completed. A similar result was obtained with seedling of *R. Soulieana*.

Because of the similarity of symptoms of the other two mosaics, the probability of considerable variation in symptoms of each of them in different varieties, and the fact that most of the field observations were made before the distinction between rose mosaics 2 and 3 became apparent, all of the rose varieties which were noted as exhibiting chlorotic lines, bands, and broad blotches in the leaf blade are here grouped together. They are: Belle of Portugal, Briarcliff, Cecile Brunner, Dazla, Dorothy Perkins, Duchess of Wellington, Duchess of York, Etoile de Hollande, General MacArthur, Golden Dawn, Golden Ophelia, F. J. Grootendorst, Hadley, Hollywood, Independence Day, Irish Elegance, Irish Fireflame, Kaiserin Auguste Viktoria, Lady Margaret Stewart, Los Angeles, Louise Catherine Breslau, Mme. Edouard Herriot, Mme. la Générale Ardouin, Mrs. Aaron Ward, Mrs. E. P. Thom, Mrs. Henry Bowles, J. Otto Thilow, Paul's Scarlet Climber, Pink Cherokee Rose, Queen Alexandra, Souvenir de Claudius Pernet, Sparkler, Sunkist, Talisman, Ville de Paris, and William F. Dreer. It is entirely possible

that some of the varieties listed here were affected by diseases other than mosaics 2 and 3 and not yet differentiated from them.

The four common stocks are readily infected by rose-mosaic viruses 2 and 3. The symptoms of both diseases are somewhat less conspicuous on *Rosa chinensis* var. *Manetti* than on *R. odorata* and Ragged Robin. One strain of *R. multiflora* produced mild symptoms with mosaic 3 and somewhat stronger mottling with mosaic 2. A variety received under the name *R. multiflora Grifferaie* developed strong symptoms with mosaic 3.

Plants of the native species *Rosa californica* and *R. nutkana* inoculated with rose mosaics 2 and 3 by inarching have not shown any symptoms up to 18 months after inoculation.

The apple mosaic has been seen by us only on the rose varieties Belle of Portugal, Hollywood, and Independence Day inoculated in the greenhouse. The susceptibility of *Cotoneaster Harroviana*, *Eriobotrya japonica*, *Photinia arbutifolia*, and *Sorbus pallescens* to apple mosaic after inoculation by grafting has been pointed out in an earlier paper (*10*). Since that time striking symptoms have been obtained by inoculation on *Pyrus spectabilis*, and mild symptoms on a *Sorbus* purchased under the name *S. sitchensis* but in appearance suggesting *S. aucuparia*.

The Winters-peach-mosaic virus appears from inoculation tests to have a rather extensive range of susceptible plants including apricot, almond, and peach, as well as the roses that have been infected by inoculation. No symptoms have been found on a number of rose varieties growing in a garden adjoining a peach orchard in which this disease has been present since 1936 or earlier. Attempts to transmit this disease from peach to *Rosa californica*, *R. multiflora*, and *R. nutkana* have not produced visible symptoms.

Small-scale attempts were made to transmit viruses 1, 2, and 3 to peach seedlings by inarching (8 plants all told). Symptoms on the peaches were doubtful at most, and attempts to recover the viruses have failed.

Seedling apple trees were likewise inoculated with viruses 2 and 3. No evidence of infection with rose mosaic 2 was apparent up to 14 months from the time of inoculation. Of ten plants inoculated with virus 3, only one developed marked mosaic symptoms the following spring, similar in some respects to the common apple mosaic but lacking the pronounced vein clearing of that disease and tending more toward the production of chlorotic lines and rings (fig. 6, *B*). The apple variety Golden Delicious, which is highly susceptible to the apple mosaic, did not develop any clear symptoms during 15 months after inoculation with virus 3 by inarching with the affected apple seedling.

Fig. 6.—*A*, Symptoms of Winters peach mosaic in Ragged Robin rose produced by inoculation in greenhouse; *B*, rose mosaic 3 in seedling apple leaves.

BASIS FOR THE SEPARATION OF DISTINCT MOSAIC DISEASES IN THE ROSE

The tendency has been in the past to group all the mosaic symptoms of the rose together as representing a single disease, although several workers have apparently suspected the existence of more than one disease (*3, 16*). It is desirable, therefore, to present more specific evidence in support of the above designation of separate diseases.

Rose mosaic 1 is readily separable from the other diseases considered here by symptoms alone, as well as by the results of inoculations of key varieties and species. Evidence of the latter kind was obtained by grafting scions affected by this disease on healthy plants of Cecile Brunner and Independence Day. Such combinations have been grown for as long as four years without the development of any definite symptoms on these two varieties. On the other hand the same varieties develop strong symptoms when inoculated with virus 2.

The separation of mosaics 2 and 3 is more difficult. Both these diseases and the mosaics of apple and peach may at times produce symptoms on roses which are very similar. On the variety Hollywood, rose mosaics 2 and 3 may be distinguished fairly readily by symptoms alone when compared side by side under similar environment (figs. 5 *A*, *C*). The reaction of Belle of Portugal is also of assistance. With the onset of disease in this variety, rose mosaic 3 produces short necrotic lines or bands along and including the mid-vein and larger lateral veins of younger leaves and later considerable distortion of the leaf blade. The disease then becomes systemic and produces largely chlorotic symptoms. This reaction has not been noted with mosaic 2 nor with the apple mosaic in this variety. Also the Souvenir de Claudius Pernet variety, which is one of the most susceptible to mosaic 3 of those tested, has failed to show any symptoms of mosaic 2 up to 18 months from the time of inoculation.

The apple mosaic is separable from the others by the extremely slow rate of development in the rose, requiring 20 to 27 months to produce symptoms 6 inches below the point of inoculation. The symptoms of this disease are also distinctive in certain respects, notably in the varieties Hollywood and Independence Day (fig. 5, *B*), in which the chlorosis and constriction in a localized area across the leaflet is frequently seen.

The Winters peach mosaic may be separated from rose mosaics 2 and 3 by the apparent failure of viruses 2 and 3 to infect peach, the absence of lines and rings when the peach virus is in Hollywood and Ragged Robin, the presence of discontinuous chlorotic bands along the veins, and the marked tendency of chlorotic areas to become green with age.

RELATION OF STOCKS TO DISEASE IN SCION VARIETY

In a preliminary trial, scions of Pilgrim and Premier Supreme affected by rose mosaic 1 were grafted on the stocks of *Rosa chinensis* var. *Manetti*, *R. multiflora*, *R. odorata*, and Ragged Robin. Although some of these plants were kept under observation for several years, there was no indication that the stock influenced the severity of the disease in the scion variety.

That such a case may be found, however, is indicated by the fact that Belle of Portugal, affected by mosaic 2 and grown on its own roots, has shown less severe symptoms than the same variety with the same disease grown on *Rosa chinensis* var. *Manetti* and Ragged Robin rootstocks.

SYMPTOMLESS CARRIERS

As is the case with many mosaic diseases, all of those under consideration here may fail to exhibit symptoms in some or all of the leaves of an affected plant at any given time. With all except rose mosaic 1, symptoms seem to be favored by relatively low temperatures and tend to be masked at higher temperatures. No controlled experiments have been made on this point, however. Mosaic 1 is often masked for considerable periods in the common rootstocks. A few instances have been noted in which top varieties (Cecile Brunner, Independence Day, Mrs. Charles E. Russell, Souvenir de Claudius Pernet) have been exposed by grafting to virus 1 and kept so for many months (as much as four years) without exhibiting symptoms at any time. In one such case, the virus was recovered from a plant of Independence Day by grafting a healthy Hollywood scion on the side opposite the point of inoculation. The Hollywood scion promptly developed symptoms showing that the virus is at least able to pass through the Independence Day.

DISSEMINATION

Beyond budding and grafting, the method of spread of the mosaic viruses in the fields and greenhouses is not known. Particular emphasis has been placed by several workers on the shipment of rootstocks as a means of dissemination. This is no doubt of some importance, particularly with virus 1 which, at the most, produces relatively inconspicuous symptoms on the common rootstocks. Surveys in the field are not likely to be of much assistance in determining the prevalence of rose mosaic 1 in the stocks unless these are already budded to the more susceptible top varieties. In the course of this work, 3 lots of *Rosa chinensis* var. *Manetti* and 1 each of *R. odorata*, *R. multiflora*, *R. Multiflora Grifferaie*, and

Ragged Robin have been used in various experiments, including grafting to healthy top varieties, without any evidence that any of them had previously been infected by mosaic 1.

Some observations indicate, on the other hand, that the budwood of the top variety has not received sufficient attention as a source of virus (*13*, *15*). For example, in a nursery where the plants were budded in place in the nursery row, rose mosaic (2 or 3) occurred in groups of 3 to 5 consecutive plants in the row, each group representing about the number that would result from a single bud stick. Also may be cited the case of a grower of roses in greenhouses who made a particular effort about five years ago to secure mosaic-free rootstocks. This was apparently done, since these stocks have been grown at Berkeley for several years both with and without grafting to healthy top varieties and have never produced any mosaic symptoms. Nevertheless, mosaic 1 continues to be more or less prevalent in some of the varieties raised by this grower.

One grower pointed out a fact which has probably led to the selection of diseased plants, in some cases, as sources of budwood. An experienced rose grower is able to detect at an early stage the defective buds that appear on affected plants (mosaic 1). Whether or not he is aware of mosaic, these buds are removed in the hope that the plant will produce other normal buds before the cutting season is past. In a variety that is not greatly reduced in vigor by the disease, this practice leaves the affected plants at the end of the harvest season larger and more vigorous in gross appearance than adjacent healthy plants which have been heavily cut for the flowers, and leads in some cases to the singling out of these diseased plants as a source of buds for propagation.

HEAT TREATMENTS OF AFFECTED CUTTINGS

Although exposure to high temperatures has been used successfully in only a few cases (*6*) in inactivating virus in vegetative plant parts, this remains the only method of any particular promise. One test with negative results has been reported for rose mosaic (*9*). The results obtained at the California Agricultural Experiment Station with roses are negative thus far and will be treated as briefly as is feasible.

Virus 1 survived the following three treatments when the cuttings did; but many of the cuttings died.

a) Cuttings were planted in a cutting box in sand held at approximately 30° C. The cuttings were completely covered by the sand for initial periods of 11 and 26 days and then uncovered at the tip, followed in the latter case by an additional period of 53 days in the warm sand which dropped to about 28° C toward the end of the period.

b) Cuttings in moist sphagnum and wrapped in waxed paper were held for 9 and 14 days at 36° C.

c) Cuttings were immersed in water at 45° C for 15 and 30 minutes.

Cuttings exposed to an air temperature of 55° C for 30 and 60 minutes did not survive. The cut surfaces were covered by an asphalt emulsion during the treatment.

Virus 2 survived in cuttings completely covered for 11 days with moist sand at 30° C. Cuttings with the basal ends in water exposed for 15 and 30 minutes to an air temperature of 55° did not survive.

Cuttings affected by mosaic 3 immersed in water at 45° C for 45 and 90 minutes remained alive for as much as 4 weeks but all died without making any growth.

DISCUSSION

Since rose mosaic 1 seems to be the common disease of greenhouse roses capable of causing direct loss in yield of desirable flowers, and since the other diseases under discussion are sufficiently conspicuous to be more easily avoided in the selection of cuttings and budwood of both stocks and top varieties, the former is in particular need of further study. The stocks grown out of doors are soon marked, more or less, by the feeding of leafhoppers and other insects. This obscures largely or entirely the symptoms which are, at best, discernible with difficulty by any means except grafting with a known susceptible variety. More specifically, the determination of the identity and habits of the vector of mosaic 1 seems imperative for any program looking toward the maintenance of disease-free stocks.

In view of the number of distinct diseases which have emerged in the course of this work from a small number of collections, it seems probable that much is yet to be done in the separation of specific mosaic diseases of the rose and in the determination of their relation to diseases of other plants.

The adoption of the somewhat paradoxical procedure of selecting a more susceptible stock may prove advisable in order to facilitate the eradication of rose mosaic 1 by roguing. The resistance of certain species and varieties to particular diseases, however, suggests the possibility that rose stocks may eventually be found which are not even symptomless carriers of these diseases.

For the immediate future, a more careful selection of budwood seems to be the obvious way of greatly reducing mosaic 1 in roses to be grown in greenhouses. Since this disease seems to spread relatively slowly in greenhouses where insect control is consistently practiced, the roguing out of diseased plants during the first season in the greenhouse is indi-

cated. In a greenhouse where 50 per cent of the plants were infected originally, one worker has reported (*1*) the reduction of the disease to a minimum by roguing. Plants removed at an early stage can be replaced, or failing this the neighboring densely set plants will often occupy most of the available space or all of it.

SUMMARY

Three distinct mosaic diseases of the rose were found in central California. These are designated as rose mosaics 1, 2, and 3. Methods for distinguishing the diseases from each other are presented. In addition, roses were infected by inoculation with apple-mosaic virus and the virus of a disease of peach designated as "Winters peach mosaic."

The use of buds from diseased plants seems to be an important means of introducing the diseases.

The virus of rose mosaic 1 survived heat treatments which were near the limit of tolerance of the rose cuttings. Virus 2 withstood exposure at 30° C for 11 days.

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